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WIND TUNNEL TEST OF THE JUNKER L-6 MONOPLANE

(AIRPLANE SECTION, S. & A. BRANCH)

▽

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REPORT OF WIND TUNNEL TEST OF THE JUNKER L-6 MONOPLANE.

OBJECT OF TEST.

A 1/30 scale model of the JL-6 monoplane was constructed at McCook Field and tested at Massachusetts Institute of Technology during April, 1921, at a velocity of 30 miles per hour. Tests were run at six different elevator settings, $-10°$, $-5°$, $0°$, $+5°$, $+10°$, and $+15°$. Lift, drag, L/D, and moment about center of gravity were determined. The wing alone was tested at 30 miles per hour to determine lift, drag, L/D, center of pressure, and moment coefficient at various angles of attack from $-8°$ to $+20°$. In addition, a number of runs were made, using the tail as an exploring plane, to determine the influence of the body on the down wash. Angle of attack is measured between the wing chord and the wind in every case. All runs on the model were made with the stabilizer set at 0° to the thrust line. Elevator and stabilizer settings refer to thrust line.

RESULTS.

With the elevator at 0° the maximum L/D is 7.3. The ratio of maximum lift to minimum drag is 21.65. Maximum L/D occurs at angle of attack of $5\frac{1}{2}°$, maximum lift at 17°, and minimum drag at $-3°$. With the stabilizer and elevator at 0° to the thrust line, the model does not balance at any angle of attack for which it was tested, but is slightly tail heavy. A small positive angle of attack of the tail plane would be necessary to secure balance.

The results on the wing alone show a maximum L/D of 13.6, a maximum Ky of 0.00377, and a minimum Kx of 0.000071. The ratio of maximum lift to minimum drag is 53.1.

The down-wash tests show that the rather unusual bump in the moment curve of the model is due to the blanketing of the tail by the body at high angles of attack. This bump begins at about 12° angle of attack and reaches a maximum at about 16°. The bump did not occur when a test was run with the tail and wings in their proper positions, but without the body.

Tables 1 to 6, inclusive, give the numerical results, and Figures 1 and 2 the graphical results of the complete model. Table 7 gives the numerical results and Figures 3, 4, and 5 show the graphical results for the wing alone. Tables 8 to 12, inclusive, give the numerical results and Figures 6, 7, and 8 show the graphical results of the down-wash experiment. Table 13 compares the wing alone to the U. S. A.-27 wing. Figure 13 is a three-view drawing of the model.

DISCUSSION.

The L/D for the model has a double maximum, one at $5\frac{1}{2}°$ and the other at 16°. The L/D hold a high value over a considerable range of angles of attack. It does not fall below 6.3 from $+1\frac{1}{2}°$ to 17°. The moment curve for the model is rather unusual in the fact that it is nearly independent of angle of attack from $-6°$ to $+12°$. This is true at elevator settings from $-10°$ to $+5°$. At about 12° angle of attack a critical point occurs in the moment curve, the cause of which is discussed under down wash. From the critical point the curve rises rapidly to a maximum value at about 17° angle of attack.

The test of the wing alone shows no unusual features.

DOWN WASH ON THE JUNKER L-6 MONOPLANE.

Due to the critical point in the moment curve of the pitching moment about the center of gravity for the Junker L-6, it was thought it would be of interest to investigate the down wash due to both the body and wings for this model. To determine the down wash due to the wings alone, the model was supported in the presence of the wing as shown in Figure 14, and the tail surface was turned for each incidence setting of the wing to the angle of zero lift. As the angle of zero lift for the tail alone had already been determined by previous test, the angle of down wash due to the wings was found by subtraction. To determine the down wash on the tail due to combination of body and wings, the model was supported as indicated in Figure 15. The tail again was on the movable head of the balance and the model and wings were mounted as before. The wing incidence was changed as in the previous case and the angle of zero lift on the tail noted. The angle of down wash is as before the difference between the angular setting required to obtain zero lift when the tail is tested alone and when tested in presence of the wing and body. The tail in both cases was used as an exploring plane. In Figure 7 the results of the two aforementioned experiments have been plotted, the wing incidence being plotted against the down-wash angle. It is to be noted that the down wash for the wings alone behaves in an ordinary fashion, but that the down wash due to the wings and body has a critical point at 12°. This confirms the belief that the body is undoubtedly the factor which causes the critical point in the pitching moment curves.

There has been plotted in this same figure a curve indicated as calculated down wash. This calculation is explained on page 15. It does not, however, allow for the slowing of the wind speed in the proximity of the tail due to the presence of the wings and body. The curves noted as experimental down wash are correct in that they allow for the presence of the wings and body, but unfortunately the effect of the propeller slipstream is ignored. This is an important factor, and it is hoped that at some future time facilities will permit of an investigation of the combined effect of propeller, wing, and body down wash on the tail.

In Figure 8 the lift coefficient for the Junker L-6 wing section has been plotted against the down-wash angle.

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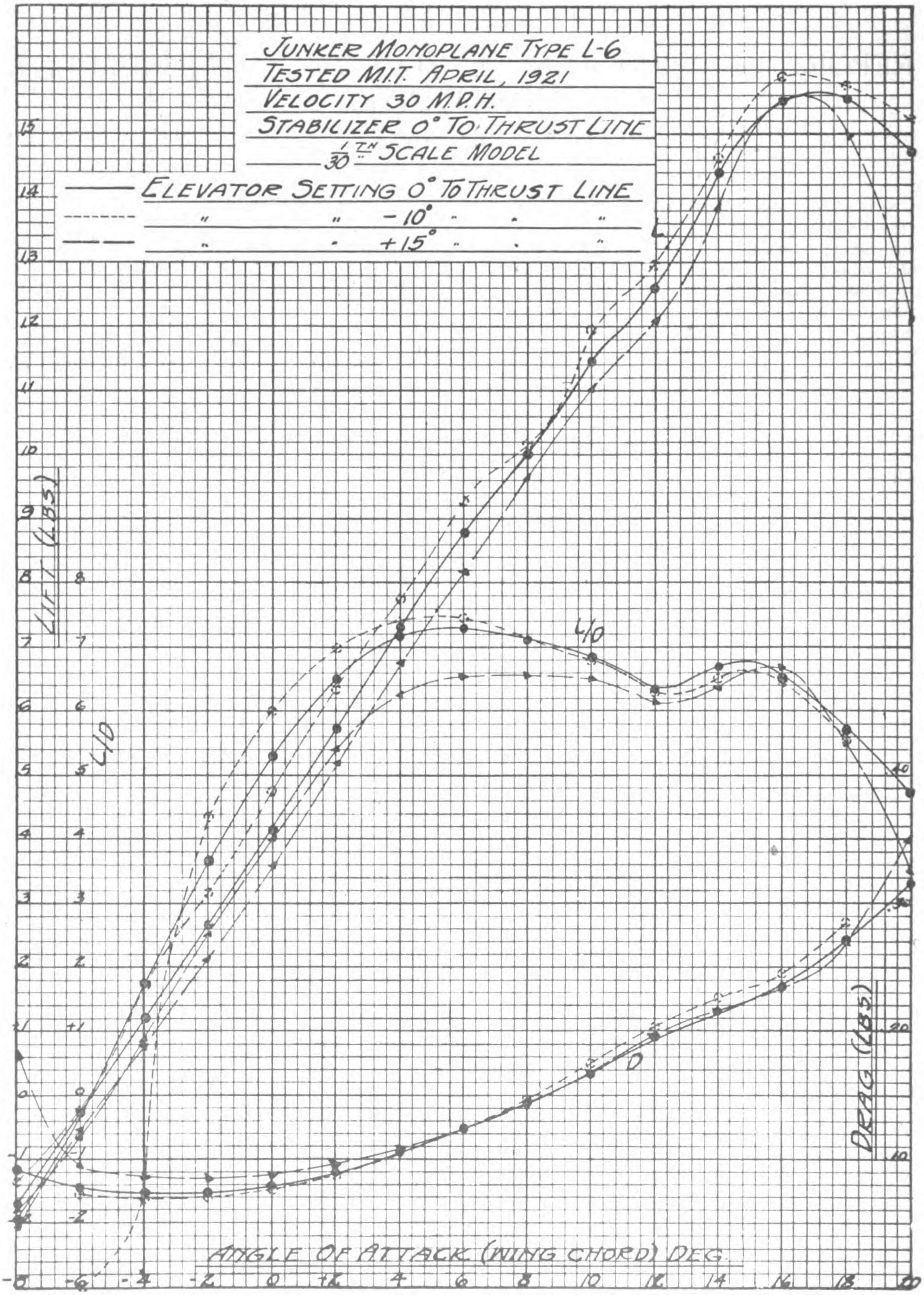

FIG. 1.

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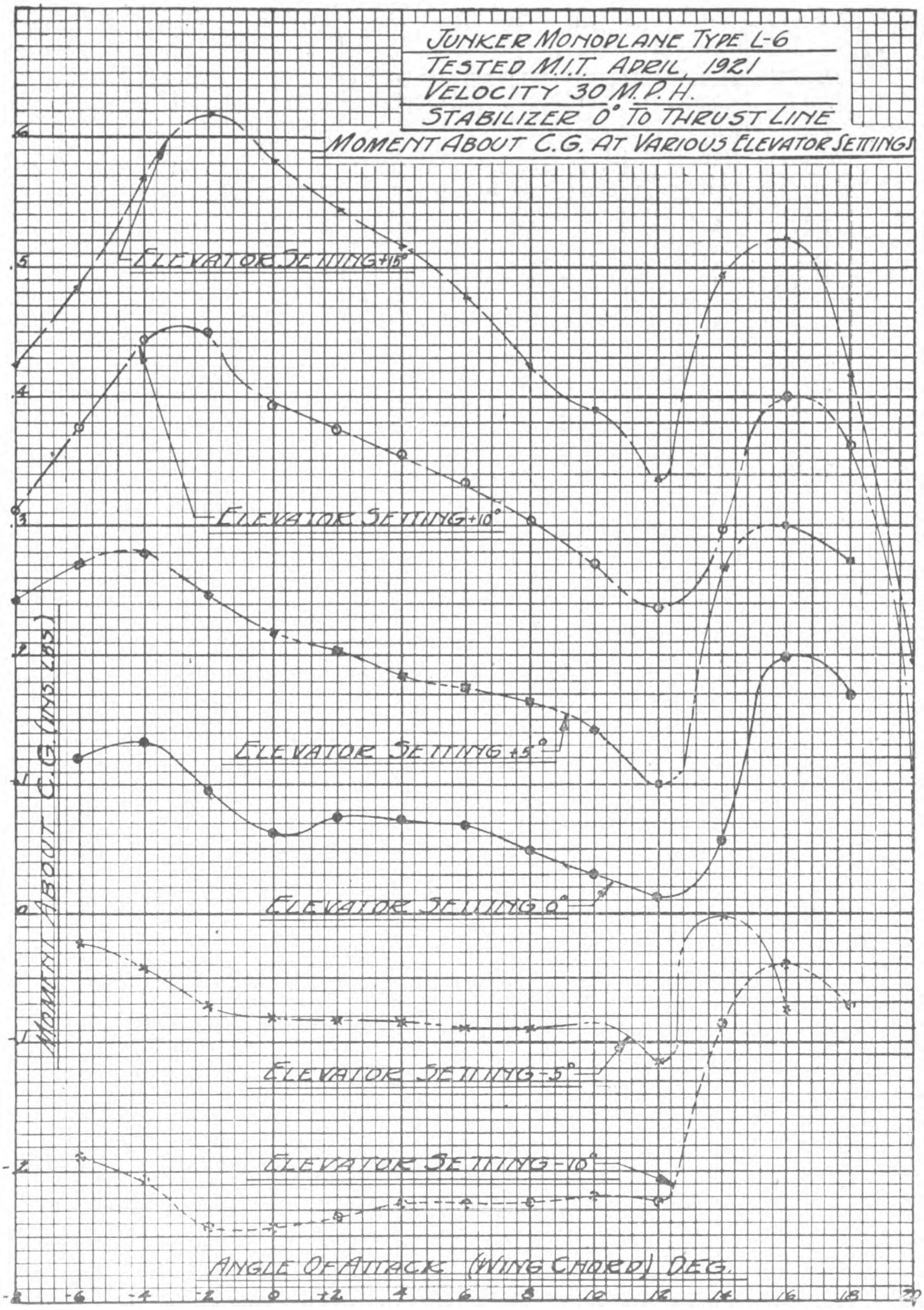

FIG. 2.

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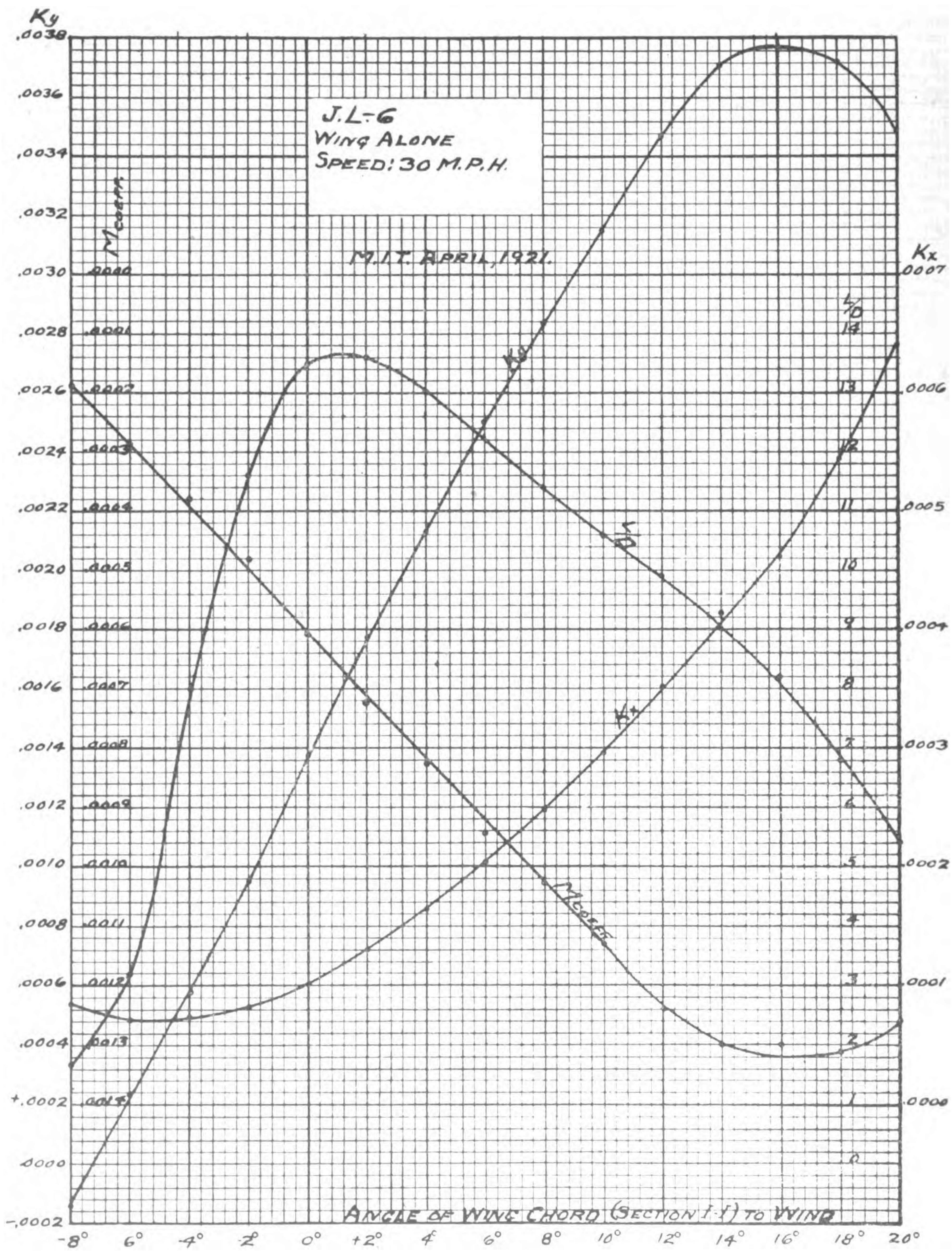
J.L-6
WING ALONE
SPEED: 30 M.P.H.
M.I.T. APRIL, 1921.
Ky
Kx
L/D
Mcoeff.
ANGLE OF WING CHORD (SECTION I-I) TO WIND
-8° 6° 4° 2° 0° +2° 4° 6° 8° 10° 12° 14° 16° 18° 20°

FIG. 3.

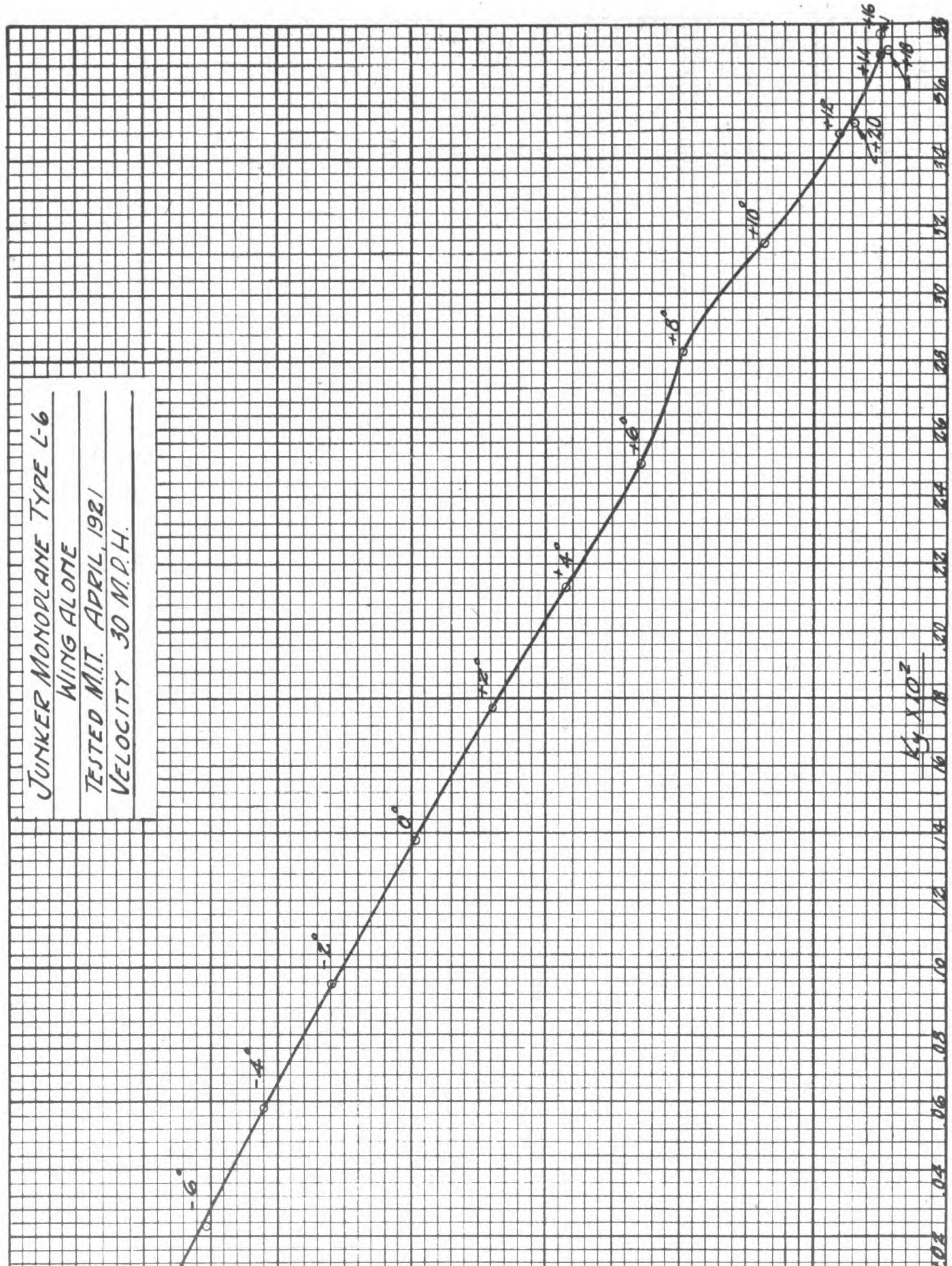
JUNKER MONOPLANE TYPE L-6
WING ALONE
TESTED M.I.T. APRIL, 1921
VELOCITY 30 M.P.H.
MOMENT COEFFICIENT X 10
Ky X 10²

FIG. 4.

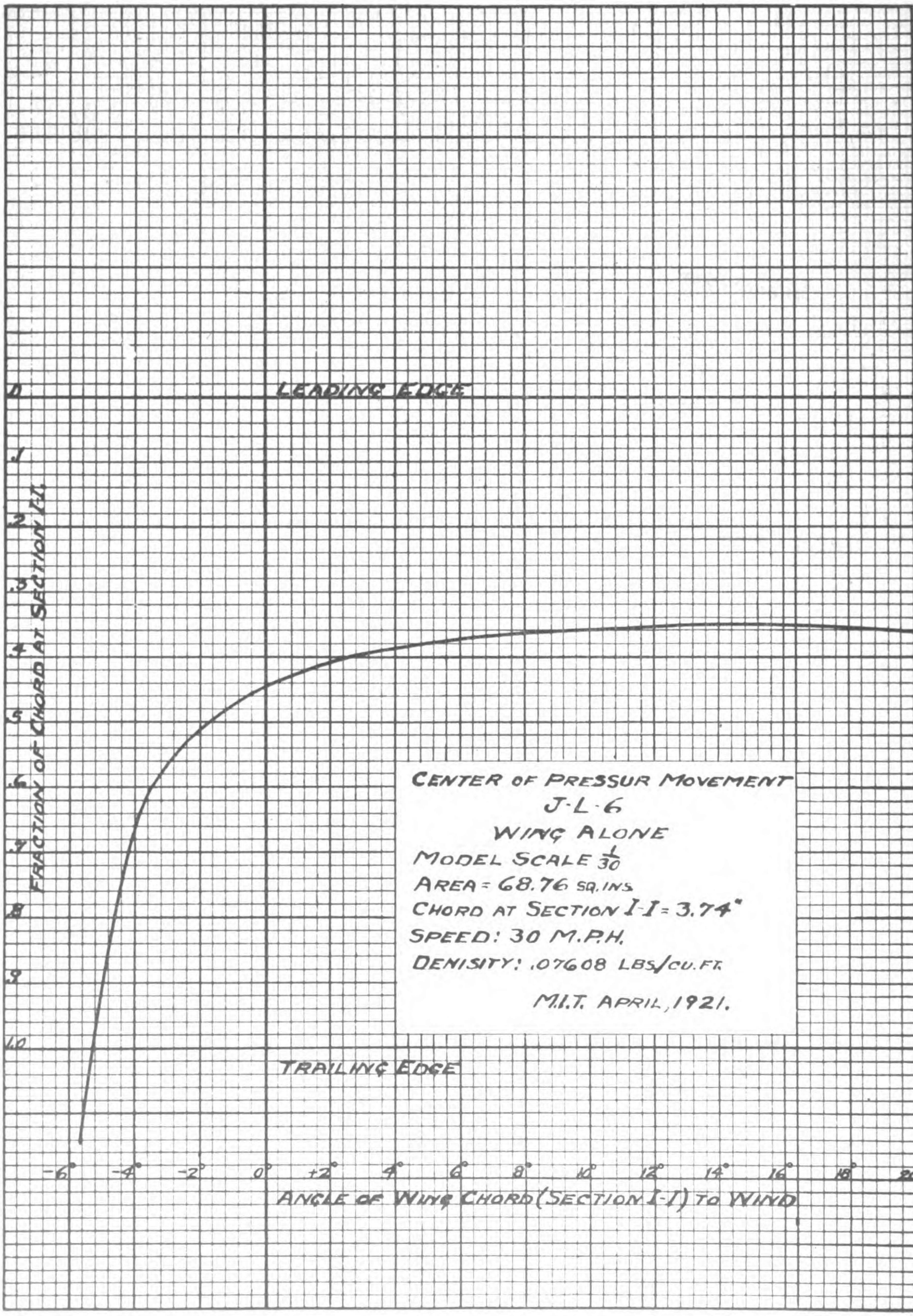

FIG. 5.

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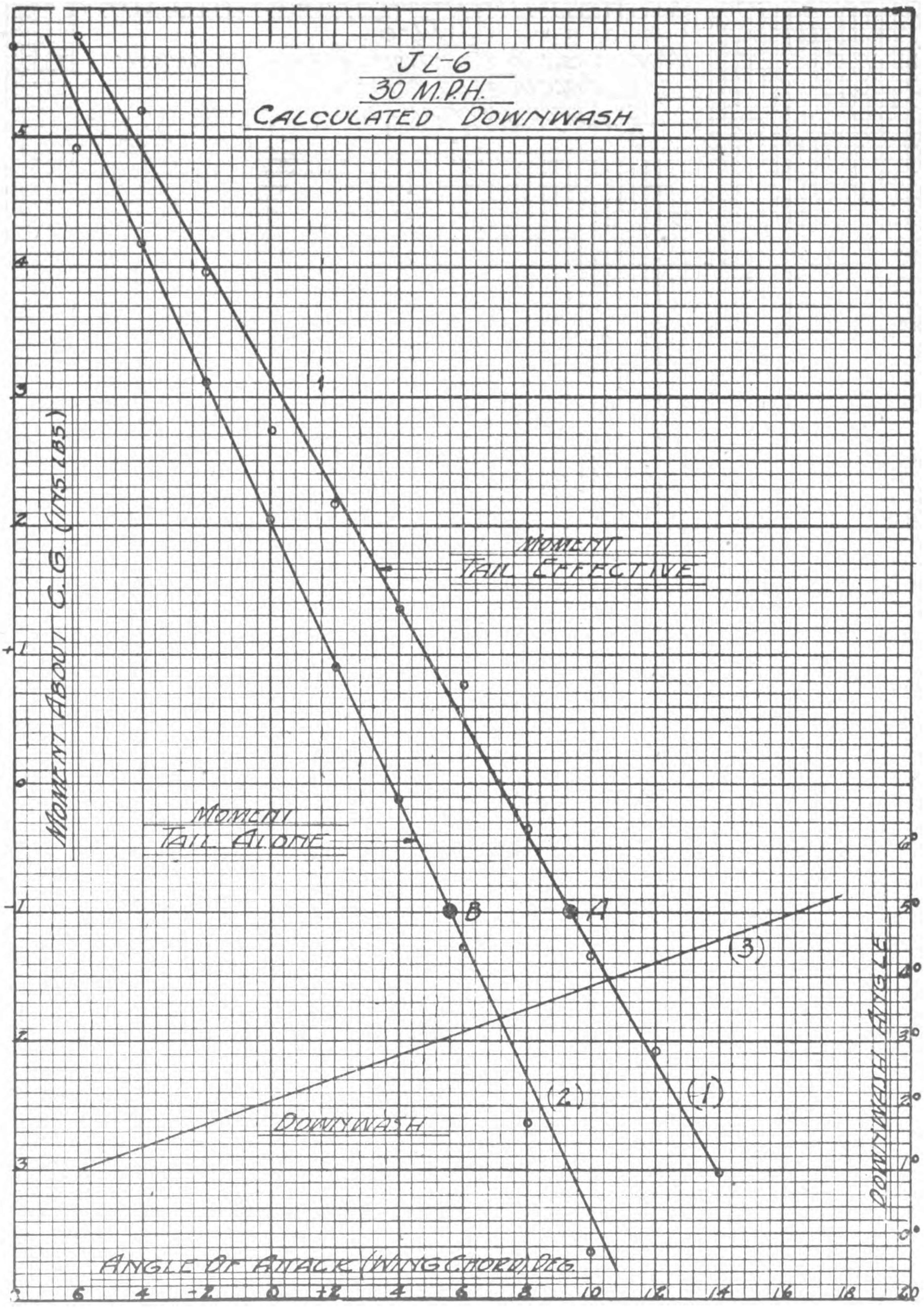

JL-6
30 M.P.H.
CALCULATED DOWNWASH
MOMENT
TAIL EFFECTIVE
MOMENT
TAIL ALONE
DOWNWASH
MOMENT ABOUT C. G. (FT.LBS)
DOWNWASH ANGLE
ANGLE OF ATTACK (WING CHORD) DEG.
B
A
(1)
(2)
(3)

FIG. 6.

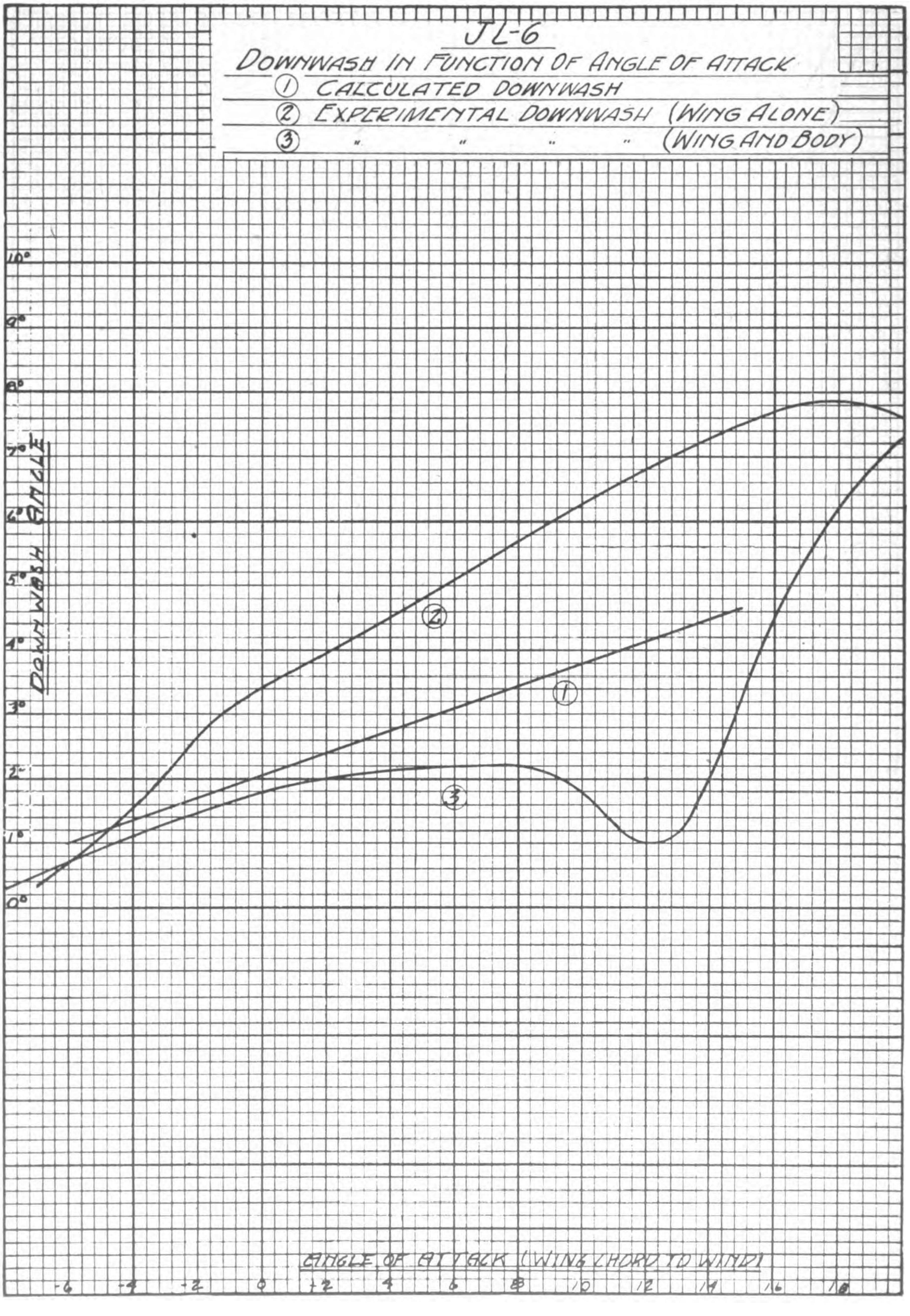
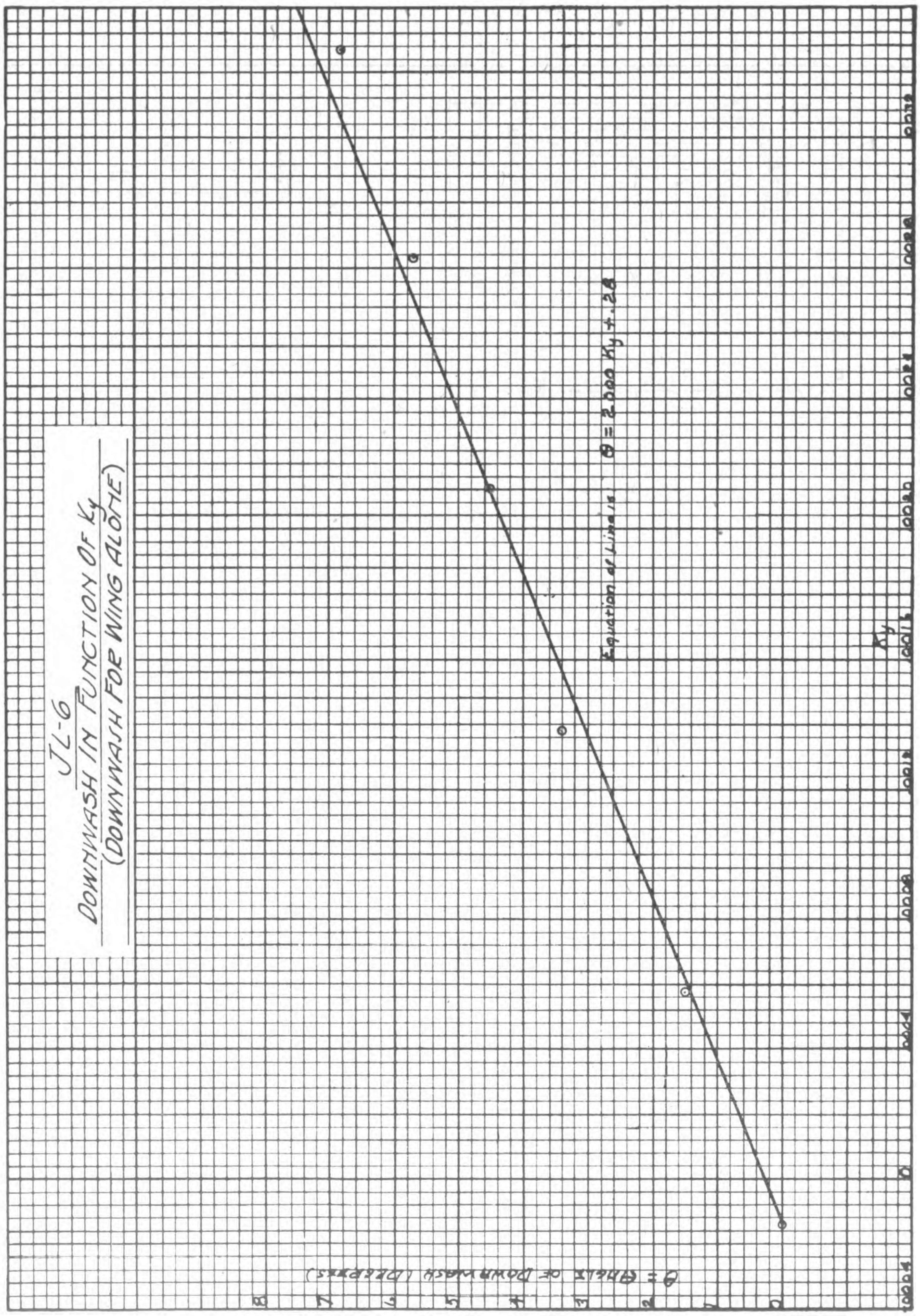

JL-6
DOWNWASH IN FUNCTION OF ANGLE OF ATTACK
① CALCULATED DOWNWASH
② EXPERIMENTAL DOWNWASH (WING ALONE)
③ " " " " (WING AND BODY)
DOWNWASH ANGLE
10°
9°
8°
7°
6°
5°
4°
3°
2°
1°
0°
ANGLE OF ATTACK (WING CHORD TO WIND)
-6
-4
-2
0
+2
4
6
8
10
12
14
16
18

FIG. 7.



JL-6
DOWNWASH IN FUNCTION OF Ky
(DOWNWASH FOR WING ALONE)
Equation of Line is θ = 2,000 Ky + .28
Ky

FIG. 8.

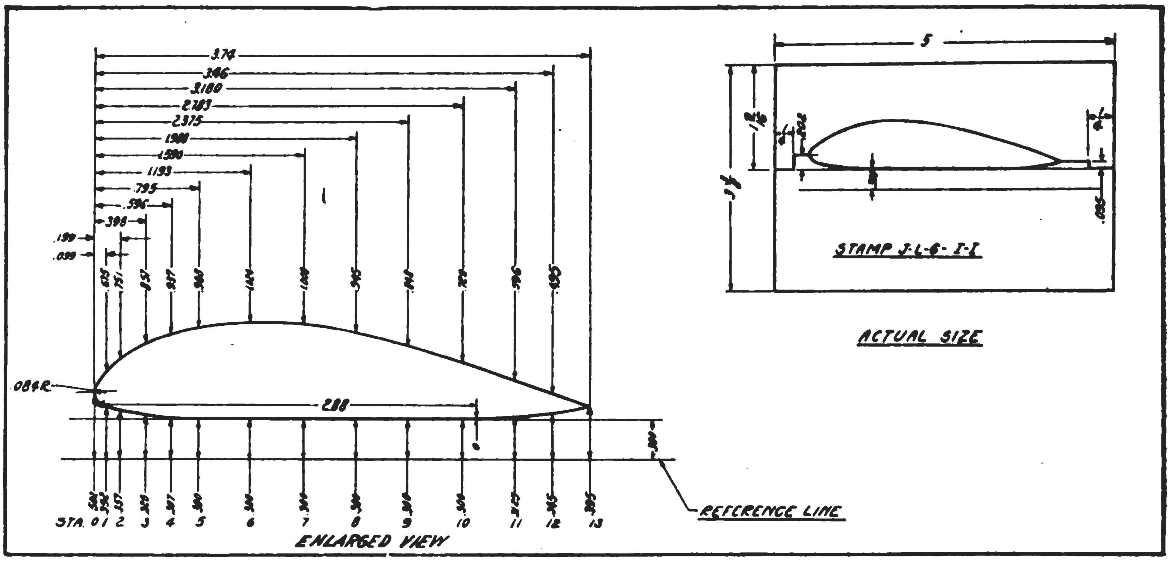


FIG. 9.—Template for aerofoil section I-I JL-6.

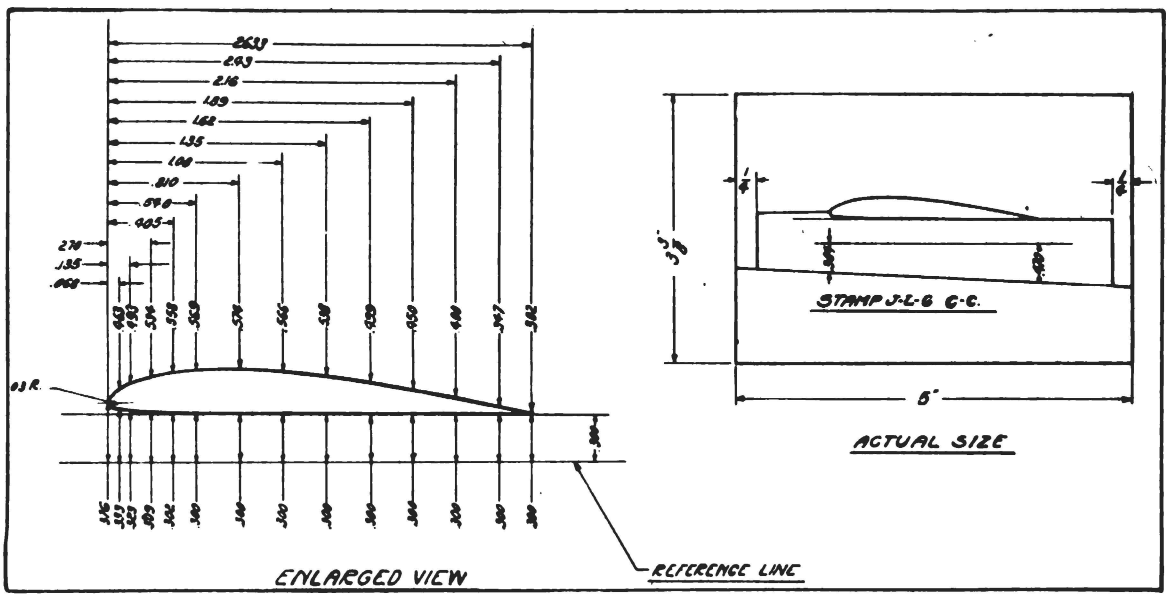


FIG. 10.—Template for aerofoil section C-C JL-6.

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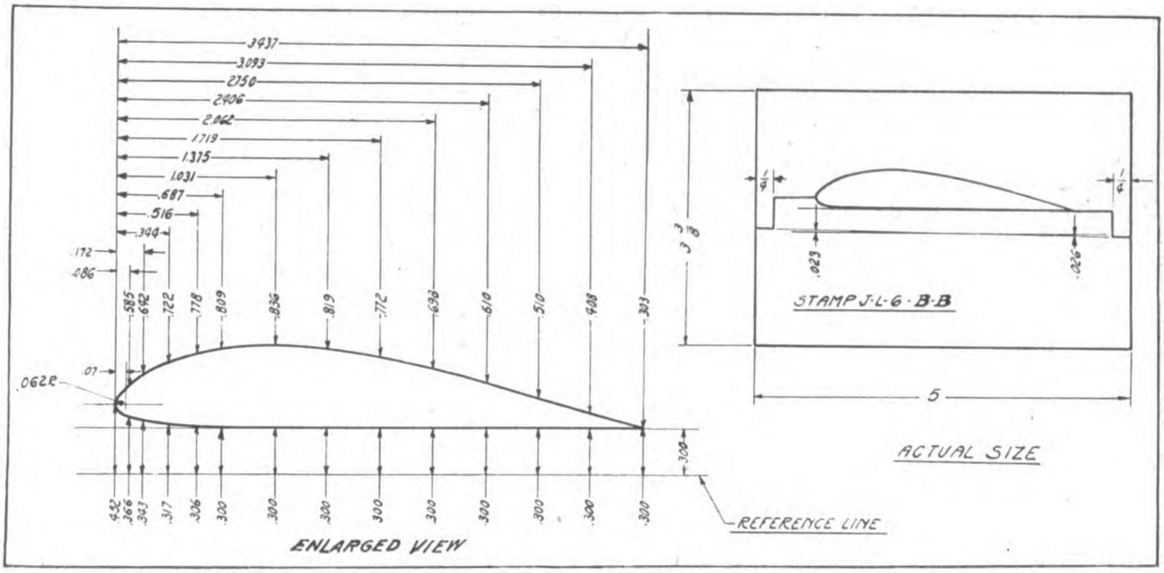

FIG. 11.—Template for aerofoil section B-B JL-6.

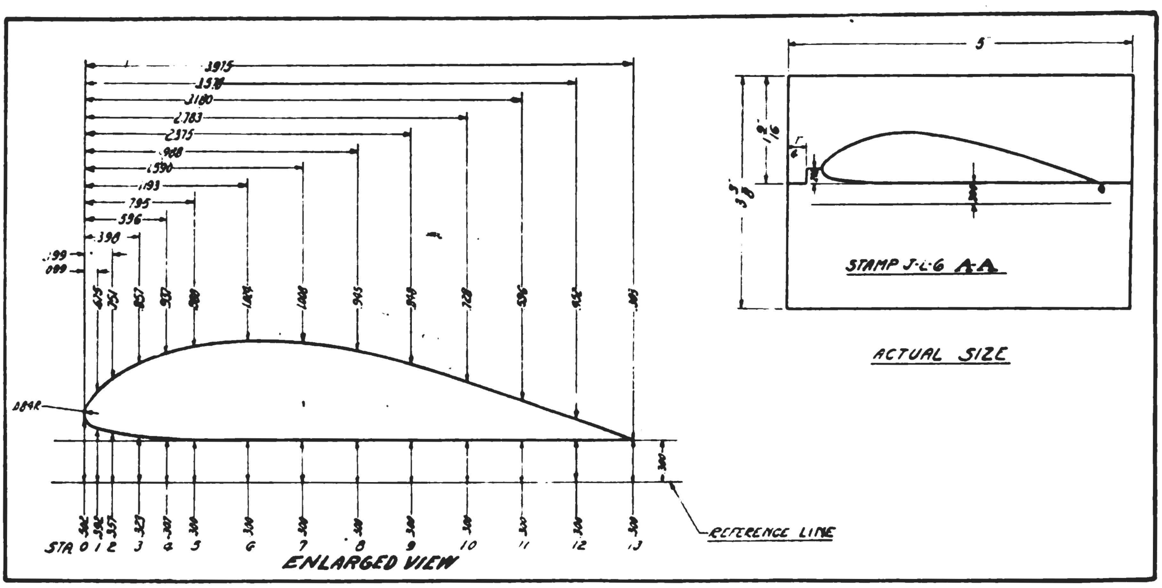

FIG. 12.—Template for aerofoil section A-A Junker JL-6.

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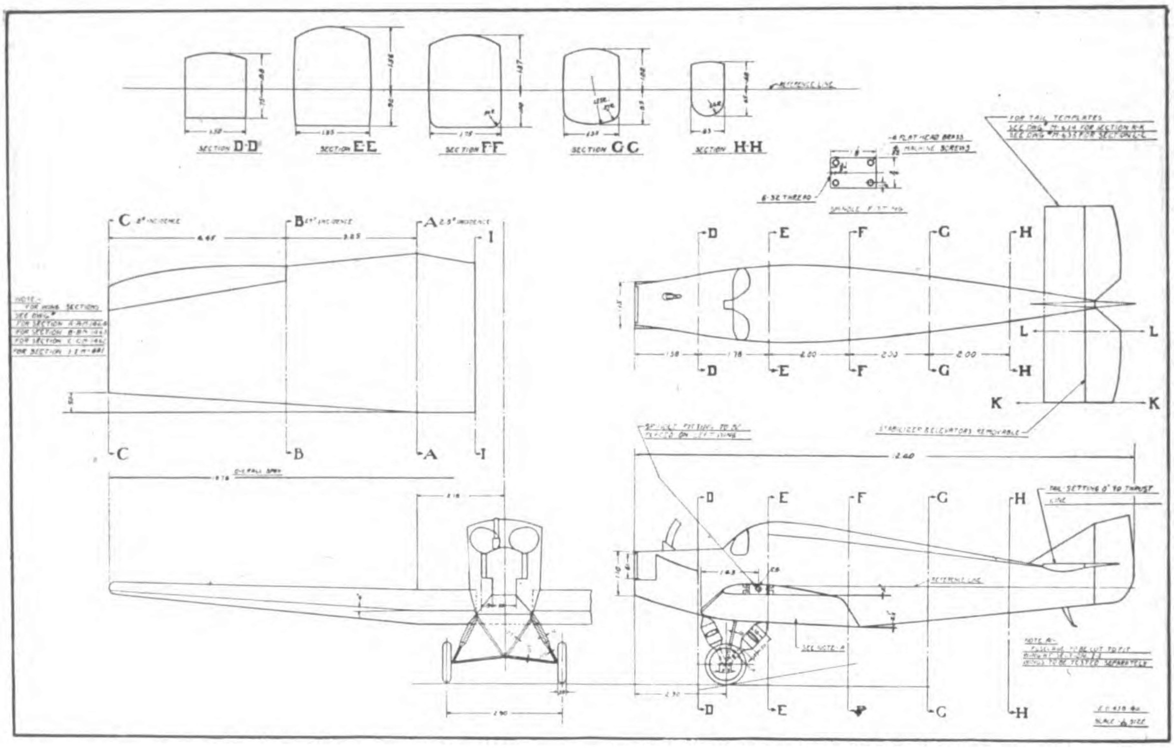

FIG. 13.

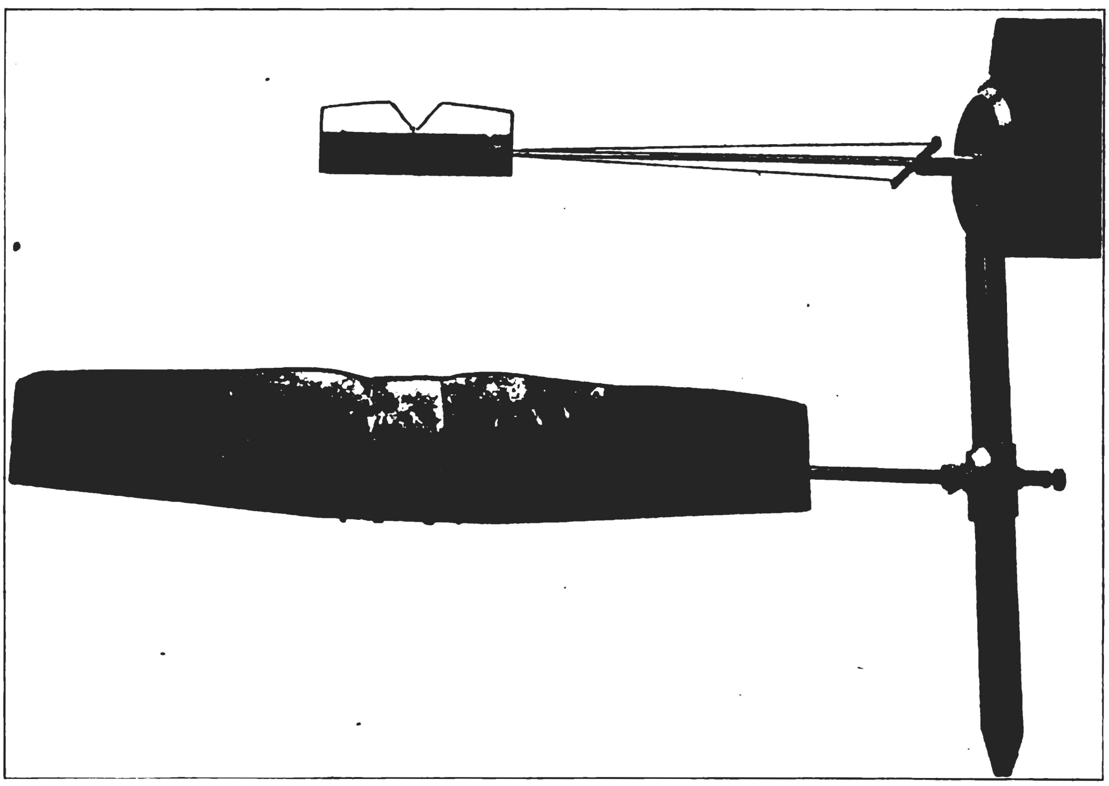

FIG. 14.

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As lift is imparted to a wing by virtue of the downward momentum given to the air, the down wash should be zero for zero lift. The down-wash angle is seen to be a linear function of the lift coefficient, as has been found to be the case for other wings.

The wing alone shows no peculiarities, as has been before noted, but this experiment has brought out very clearly the fact that account must be taken of the body in the calculation of down wash.

the tail plane to the horizontal is 3.8° greater at point A than at point B. Then the angle of the wind stream to the horizontal must also be 3.8° greater at point A than at point B, or the angle of down wash is 3.8°. Similarly, the down wash for any point on curve (1) is the difference in angle of attack between that point and the point of equal moment on curve (2).

Curve (3) is down-wash angle plotted against angle of attack.

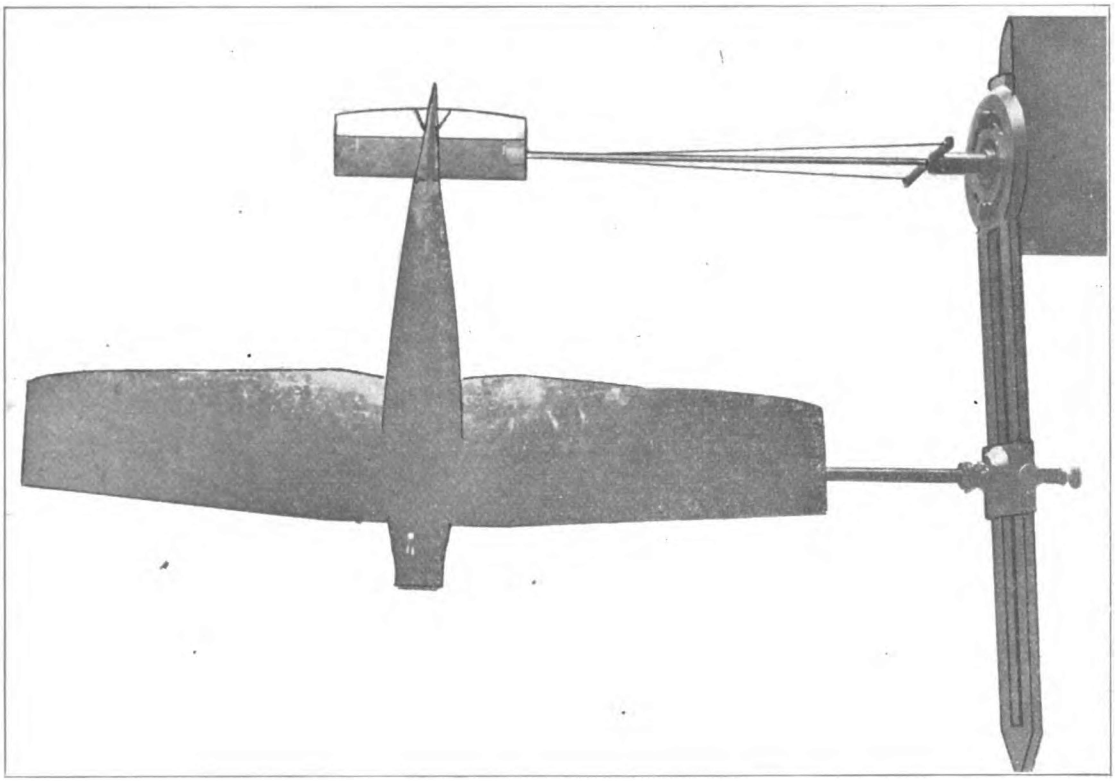

FIG. 15.

EXPLANATION OF CALCULATION OF DOWN-WASH ANGLE.

In Figure 6 the moments for the tail alone, curve (2), and for the effective tail, curve (1), are plotted against wing angle of attack. The moment for the effective tail is the difference between the moment for the complete model and the moment for the model without the tail plane. Curve (1), then, is the moment for the tail alone, but influenced by the presence of the wings and body.

With other conditions constant, the lift, and therefore the moment about the center of gravity for the tail plane, varies only with its angle of attack. In Figure 6, since the moment at point A for the effective tail is the same as at point B for the tail alone, the tail-plane angle of attack must be the same for these two points. But the angle of

TABLE 1.—*Junker L-6 monoplane (complete model).*

Authority: Aerodynamical Laboratory, M. I. T., April, 1921.
Velocity: 30 miles per hour.
Model: 1/30 size.

i	L	D	L/D	M
−8	−0.176	0.0925	−1.90	....
−6	−.026	.0782	−.33	+0.121
−4	+.128	.0719	1.78	.133
−2	.269	.0733	3.67	.096
0	.417	.0787	5.29	.061
2	.576	.0880	6.54	.077
4	.731	.1015	7.20	.072
6	.880	.1204	7.31	.067
8	1.013	.1418	7.15	.048
10	1.146	.1664	6.88	.030
12	1.257	.1971	6.37	.013
14	1.439	.2125	6.76	.056
16	1.550	.2349	6.60	.200
18	1.554	.2723	5.70	.169
20	1.479	.3137	4.71	....

Tail plane 0° to thrust line.
Elevators 0° to thrust line.

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TABLE 2.—*Junker L–6 monoplane (complete model).*

Authority: Aerodynamical Laboratory, M. I. T., April, 1921.
Velocity: 30 miles per hour.
Model: 1/30 size.

i	L	D	L/D	M
−8	−0.179	0.0961	....	+0.2437
−6	−.032	.0821	....	.2725
−4	+.112	.0757	1.48	.2795
−2	.253	.0765	3.31	.2471
0	.402	.0803	5.01	.2177
+2	.564	.0901	6.26	.2056
4	.715	.1040	6.87	.1834
6	.861	.1214	7.09	.1765
8	1.000	.1429	7.00	.1605
10	1.131	.1682	6.73	.1427
12	1.254	.1988	6.30	.1100
14	1.409	.2184	6.44	.2688
16	1.539	.2337	6.58	.3001
18	1.534	.2720	5.64	.2716
20	1.478	.3128	4.72	.2309

Tail plane 0° to thrust line.
Elevators +5° to thrust line.

TABLE 3.—*Junker L–6 monoplane (complete model).*

Authority: Aerodynamical Laboratory, M. I. T., April, 1921.
Velocity: 30 miles per hour.
Model: 1/30 size.

i	L	D	L/D	M
−8	−0.194	0.1022	....	+0.3113
−6	− .043	.0889	....	.3777
−4	+ .088	.0820	1.07	.4478
−2	.229	.0808	2.83	.4517
0	.377	.0842	4.48	.3926
+2	.534	.0919	5.80	.3767
4	.692	.1055	6.56	.3567
6	.846	.1228	6.89	.3332
8	.981	.1439	6.81	.3016
10	1.119	.1682	6.65	.2768
12	1.224	.1961	6.24	.2367
14	1.384	.2165	6.39	.2988
16	1.504	.2326	6.46	.4018
18	1.501	.2682	5.60	.3624
20	1.115	.3528	3.16	.0470

Tail plane 0° to thrust line.
Elevators +10° to thrust line.

TABLE 4.—*Junker L–6 monoplane (complete model).*

Authority: Aerodynamical Laboratory, M. I. T., April, 1921.
Velocity: 30 miles per hour.
Model: 1/30 size.

i	L	D	L/D	M
−8	−0.203	0.1082	−1.87	+0.4264
−6	− .057	.0950	− .6	.4831
−4	+ .078	.0892	+ .87	.5700
−2	.209	.0876	2.49	.6209
0	.353	.0894	3.95	.5817
+2	.524	.0965	5.43	.5466
4	.674	.1082	6.23	.5177
6	.819	.1255	6.51	.4789
8	.973	.1458	6.55	.4211
10	1.100	.1690	6.51	.3925
12	1.205	.1973	6.11	.3386
14	1.383	.2167	6.39	.4988
16	1.558	.2316	6.72	.5220
18	1.500	.2693	5.57	.4188
20	1.205	.3532	3.41	.1904

Tail plane 0° to thrust line.
Elevators +15° to thrust line.

TABLE 5.—*Junker L–6 monoplane (complete model).*

Authority: Aerodynamical Laboratory, M. I. T., April, 1921.
Velocity: 30 miles per hour.
Model: 1/30 size.

i	L	D	L/D	M
−6	+0.003	0.0752	0.04	−0.023
−4	.154	.0702	2.20	− .041
−2	.298	.0724	4.11	− .073
0	.447	.0784	5.70	− .084
+2	.608	.0889	6.84	− .082
4	.755	.1038	7.27	− .082
6	.906	.1233	6.60	− .089
8	1.041	.1454	7.16	− .090
10	1.174	.1724	6.80	− .086
12	1.289	.2032	6.34	− .115
14	1.453	.2228	6.52	− .002
16	1.568	.2400	6.54	+ .078
18	1.566	.2789	5.61	+ .043
20	1.508	....	....	....

Tail plane 0° to thrust line.
Elevators −5° to thrust line.

TABLE 6.—*Junker L–6 monoplane (complete model).*

Authority: Aerodynamical Laboratory, M. I. T., April, 1921.
Velocity: 30 miles per hour.
Model: 1/30 size.

i	L	D	L/D	M
−8	−0.133	....	....	....
−6	+ .022	0.0720	0.30	−0.187
−4	.173	.0686	2.52	− .206
−2	.317	.0720	4.40	− .242
0	.471	.0785	6.00	− .245
+2	.628	.0895	7.01	− .236
4	.774	.1047	7.40	− .226
6	.928	.1250	7.42	− .226
8	1.062	.1481	7.16	− .225
10	1.195	.1757	6.80	− .220
12	1.296	.2053	6.31	− .222
14	1.464	.2266	6.46	− .084
16	1.591	.2445	6.50	− .039
18	1.579	.2842	5.55	− .072
20	1.521	....	....	....

Tail plane 0° to thrust line.
Elevators −10° to thrust line.

TABLE 7.—*Junker L–6 monoplane (wing alone):*

Authority: Aerodynamical Laboratory, M. I. T., April, 1921.
Velocity: 30 miles per hour.
Model: 1/30 size. (Area=68.76 sq. in.)

i	Ky	Kx	L/D	C. P.	$M_{coeff.}$
−8	−0.00014	0.000084	1.66	....	−0.000188
−6	+.00023	.000071	3.2	1.300	−.000286
−4	.00058	.000073	8.0	.660	−.000380
−2	.00095	.000082	11.6	.513	−.000481
0	.00138	.000101	13.5	.443	−.000607
2	.00177	.000130	13.6	.408	−.000723
4	.00213	.000164	13.0	.387	−.000827
6	.00250	.000203	12.3	.374	−.000942
8	.00283	.000248	11.4	.365	−.00103
10	.00315	.000296	10.6	.360	−.00113
12	.00347	.000351	9.9	.354	−.00124
14	.00371	.000401	9.3	.352	−.00130
16	.00377	.000462	8.2	.350	−.00130
18	.00372	.000545	6.8	.355	−.00131
20	.00349	.000641	5.4	.361	−.00126

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Table 8.—*Junker L–6 monoplane (complete minus elevator and stabilizer).*

Authority: Aerodynamical Laboratory, M. I. T., April, 1921.
Velocity: 30 miles per hour.
Model: 1/30 size.

i	L	D	L/D	M
−8	−0.080	0.0714	....	−0.507
−6	+.076	.0630	1.21	−.456
−4	.215	.0629	3.42	−.384
−2	.345	.0678	5.08	−.303
0	.490	.0758	6.46	−.212
2	.638	.0871	7.33	−.142
4	.783	.1032	7.56	−.059
6	.922	.1230	7.50	+.011
8	1.054	.1444	7.30	.086
10	1.167	.1705	6.84	.163
12	1.270	.1993	6.36	.222
14	1.498	.2079	7.20	.362
16	1.562	.2345	6.66	.416
18	1.539	.2718	5.65	.418
20	1.485	.3128	4.74	.380

Table 9.—*Junker L–6 monoplane (elevator and stabilizer alone).*

Authority: Aerodynamical Laboratory, M. I. T., April, 1921.
Velocity: 30 miles per hour.
Model: 1/30 size.

i	L	D	L/D	M
−8	−0.065	0.0132	....	+0.571
−6	−.056	.0102	....	+.492
−4	−.048	.0076	....	+.419
−2	−.035	.0057	....	+.311
0	−.023	.0047	....	+.205
+2	−.011	.0045	....	+.090
4	+.002	.0053	0.38	−.011
6	.015	.0070	2.14	−.128
8	.030	.0098	3.06	−.263
10	.041	.0135	3.04	−.364
12	.049	.0171	2.87	−.444
14	.056	.0214	2.62	−.515
16	.062	.0261	2.37	−.583
18	.066	.0297	2.22	−.625
20	.068	.0334	2.03	−.656

Table 10.—*Junker L–6 monoplane (complete minus elevators).*

Authority: Aerodynamical Laboratory, M. I. T., April, 1921.
Velocity: 30 miles per hour.
Model: 1/30 size.

i	L	D	L/D	M
−8	−0.173	0.0921	....	....
−6	−.023	.0773	....	−0.120
−4	.125	.0740	1.69	−.050
−2	.269	.0753	3.57	+.006
0	.411	.0804	5.11	.038
+2	.568	.0898	6.32	.060
4	.728	.1036	7.04	.078
6	.877	.1214	7.22	.099
8	1.020	.1430	7.12	.116
10	1.154	.1667	6.93	.132
12	1.276	.1960	6.51	.141
14	1.450	.2163	6.70	.176
16	1.576	.2362	6.67	.331
18	1.582	.2705	6.85	.334
20	1.534	.3120	4.91	.306

Table 11.—*Junker L–6 monoplane.*

Authority: Aerodynamical Laboratory, M. I. T., April, 1921.
Velocity: 30 miles per hour.
Model: 1/30 size.

EXPERIMENTAL DOWN WASH.

Wing incidence	Ky	Down wash due to wings	Down wash due to wings and body
°		°	°
−8	−0.00014	0.0	0.3
−4	+.00058	1.5	1.1
0	.00138	3.4	1.8
+4	.00213	4.5	2.1
8	.00283	5.7	2.2
12	.00347	6.8	1.0
16	.00377	7.7	4.5
20	.00349	7.6	7.3

Table 12.—*Junker L–6 monoplane.*

Authority: Aerodynamical Laboratory, M. I. T., April, 1921.
Velocity: 30 miles per honr.
Model: 1/30 size.

MOMENTS ABOUT C. G. FOR CALCULATED DOWN WASH.

i	(1) M for complete model	(2) M for model minus tail	(3) M for effective tail	(4) M for tail alone	(5) Angle of down wash
					°
−8	....	−0.507	....	0.571	....
−6	0.121	−.456	0.577	.492	1.0
−4	.133	−.384	.517	.419	....
−2	.096	−.303	.399	.311	1.7
0	.061	−.212	.273	.205	....
+2	.077	−.142	.219	.090	2.4
4	.072	−.059	.131	−.011	....
6	.067	+.011	.078	−.128	3.1
8	.048	.086	−.038	−.263	....
10	.030	.163	−.133	−.364	3.8
12	.013	.222	−.209	−.444	....
14	.056	.362	.306	−.515	4.6
16	.200	.416	.216	−.583	....
18	.169	.418	.249	−.625	....
20	....	.380	....	−.656	....

(1) From Table 1.
(2) From Table 8.
(3) =(1)—(2).
(4) From Table 9.
(5) From Figure 6.

Table 13.—*Comparison of aerofoils.*

Aerofoil.	U. S. A.-27.	Junker.
Maximum Ky (landing)	0.00363	0.00377
Minimum Kx	.00008	.00007
Maximum L/D (cruising)	16.1	13.7
High-speed pursuit, L/D at $\frac{\text{Ky (max.)}}{9}$	4.6	5.1
High-speed reconnaissance, L/D at $\frac{\text{Ky (max.)}}{6.25}$	7.0	8.1
High-speed bomber, L/D at $\frac{\text{Ky (max.)}}{4}$	11.7	11.5
Speed range $\frac{\sqrt{\text{Ky (max.)}}}{\sqrt{\text{Kx (min.)}}}$	1.41	1.49
Ceiling and climb. constant loading $\frac{\text{Ky}^{3/2}}{\text{Ky}}$ (max. value)	.665	.61
Ceiling and climb. constant landing speed $\sqrt{\frac{\frac{\text{Ky (max.)}}{\text{Ky}}}{\text{L/D}}}$ (min. value)	.0908	.1006
Most forward position of center of pressure	27.4	35.2
C. P. travel in per cent of chord between most forward position of C. P. and position at angle of $\frac{\text{Ky max.}}{6.25}$	39.6	28.8
Moment coefficient with respect to L. E. for angle of zero lift	....	.00028
Spar depths in per cent of chord:		
10 per cent from leading edge	9.17	[1] 13.50
15 per cent from leading edge	10.40	[1] 15.75
60 per cent from leading edge	9.27	[1] 13.75
70 per cent from leading edge	7.90	[1] 9.10
Authority	M. I. T.	M. I. T.
Date test run	November, 1920.	April, 1921
Aspect ratio	6	[2] 5.5
Velocity, miles per hour	30	30

[1] At root section.
[2] Chord = area/span.

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